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Evaluation of evaporative cooler models using cotton-based fabric pads for tropical housing units

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ARTICLE INFO	ABSTRACT
Article history: Received January 19, 2022 Received in revised form June 20, 2022 Accepted June 29, 2022 Available online August 01, 2022 *Keywords:* Evaporative cooler Fabric cooling pad Public housing Thermal design Tropics ***Corresponding author**: I Gusti Ngurah Antaryama Department of Architecture, Institut Teknologi Sepuluh Nopember, Indonesia Email: antaryama@arch.its.ac.id	*Direct evaporative cooling (DEC) is a passive cooling strategy adopted in predominantly hot regions to restore building thermal comfort with less energy consumption and minimum impact on the environment. The implementation and studies of DEC in tropical housing are limited. Although DEC can reduce air temperature, an increase in relative humidity can still be seen as a disadvantage. Many materials were introduced for the cooling pads, but none was explicitly proposed for use in the housing unit. The present study explores different cotton-based fabrics to be used in the proposed evaporative cooler of the public housing unit in Surabaya. It analyses its ability to reduce air temperature and identify the increase in air humidity that may occur. A small-scale model of the housing unit that incorporates an evaporative cooling system is set, and internal air temperature and humidity are recorded. Results of the analysis show that different fabric specifications can lead to various thermal performances. A cotton-based blanket is found to be suitable for the proposed strategy*

Introduction

In Indonesia, thermal conditions in public housing, including Surabaya, are often out of the comfort level (Indrani 2008; Telis, Winandari, and Tundono 2017). Warm and humid are typical characteristics of the climate of Surabaya and pose obstacles to the comfort provision. As a resolution, occupants of the housing unit tend to equip their units with portable ceiling fans or air conditioning systems (AC). This strategy could be expensive and consumes more energy. Many kinds of research have been conducted on low-rise housing and suggest natural ventilation to restore comfort in the building (Indrani 2008; Alfata et al. 2015). It is cheaper and able to provide tolerable indoor thermal conditions.

Passive cooling can be a reliable means of providing thermal comfort in predominantly hot regions. It is affordable because most of the public housing occupants in Surabaya belong to the middle-income group. It can save energy and has a less detrimental impact on the environment. Aside from the natural ventilation mentioned above, direct evaporative cooling (DEC) can also be an alternative for cooling a building in a warm-humid climate like Surabaya. However, the utilization of DEC in warm-humid areas is limited (Mohammad et al. 2013; Yunianto 2018). This limitation owes that the use of the technique can increase internal air humidity. Even though the method can help reduce air temperature considerably, the increase in relative humidity can restrict the evaporation process in the human body and thus elevates discomfort (Poku, W. Oyinki, and A. Ogbonnaya 2017; Rao and Datta 2018). Nevertheless, several studies recommend the use of the technique if it is coupled with other strategies that can help to minimize the increase in air humidity (Yunianto 2018; Suwannapruk, Prieto, and Janssen 2020; Raza et al. 2020; Hussain et al. 2020; Chang et al. 2020; Alwetaishi et al. 2020; Suryo et al. 2000; Sajjad et al. 2021). If the increased air humidity is not too high, it can be compensated by sufficient air velocity in internal space.

Many scholars have carried out detailed studies of DEC. The studies generally considered many topics. The first was the cooling pad which covers variables such as material specifications, area, and thickness (Elmsaad and Omran 2015; Warke and Deshmukh 2017; Abohorlu Doğramacı et al. 2019; Susila, Wijaksana, and Suarnadwipa 2019; Abaranji, Panchabikesan, and Ramalingam 2020; Ahmad, Malek, and Rahman 2017; Esparza L. et al. 2018). The second airstream velocity, air temperature, and water volume in the system (Aziz et al. 2017; Warke and Deshmukh 2017; Susila, Wijaksana, and Suarnadwipa 2019), and the last integration with other techniques to improve the performance of DEC (Darmawan, Wijaksana, and Suarnadwipa 2021; Xu et al. 2016). These studies focused mainly on developing technical aspects of the cooler system, and none of them was applied explicitly to housing units. Concerning the use of fabric as a cooling pad, the studies generally focused on one type of fabric.

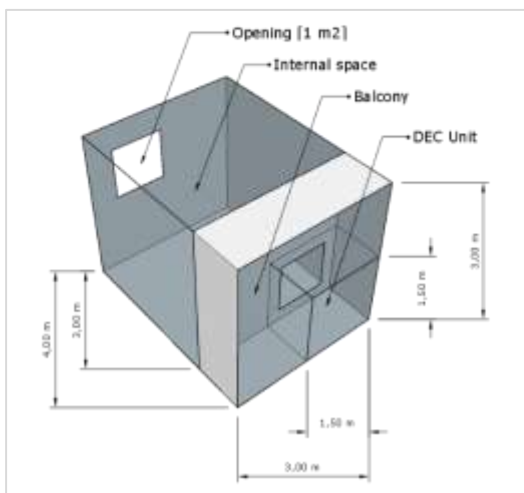
The present study is the first part of an umbrella study exploring the use of DEC in warm-humid climates, especially for public housing in Surabaya. The DEC is proposed as an alternative passive cooling technique in low-rise public housing units, and it is also suggested because it is affordable (Susila, Wijaksana, and Suarnadwipa 2019). As the first step of the exploration, the present study focuses on investigating the influence of different fabric-based cooling pad specifications on the indoor thermal condition of the housing unit, which is limited, as mentioned above. Since air humidity is of concern when adopting DEC, the study is also aimed to find a material that has less impact on the air humidity but can still lower the air temperature.

Method

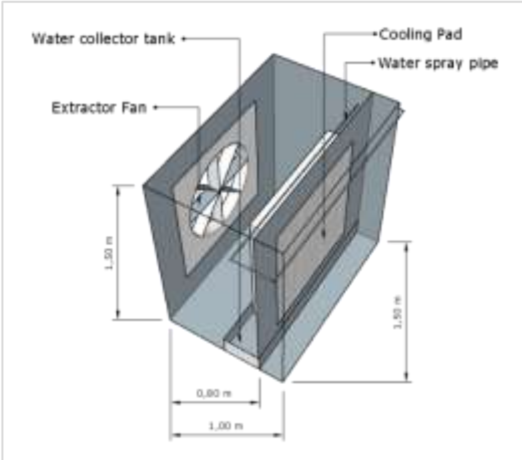
The contribution of different fabric specifications to the indoor thermal condition is investigated through a small-scale model. The model is set to represent a space with an area of 9 m^2, and it has a 1 m depth of balcony and an evaporative cooler. The dimension of the evaporative cooler unit is 1.5 m x 1.5 m x 1 m. The system uses a 1 m^2 area of the cooling pad with a 20 cm thickness. It is also equipped with a six-inch motorized fan with a capacity of 280 m^3/h (figure 1).

Two models that are scaled 1:5 are prepared. One represents the control model, and the other is the experimental model (figure 2). Due to the pandemic, the models were located in the courtyard of the author's house. The study observed no different indoor thermal behavior between the two models; therefore, the setting can be regarded as valid. The study focuses only on evaluating the influence of various fabric cooling pads on indoor thermal conditions, and no attempts were made to investigate the effect of surrounding obstructions, orientation, maintenance, or any aspects beyond the study's focus.

Experimental method was adopted as the study seeks to investigated influence of idenpendent variables (fabric specification) on dependent variables (thermal condition). Previous researches that share the same objective also use this menthod (Mohammad et al. 2013; Susila, Wijaksana, and Suarnadwipa 2019; Warke and Deshmukh 2017).



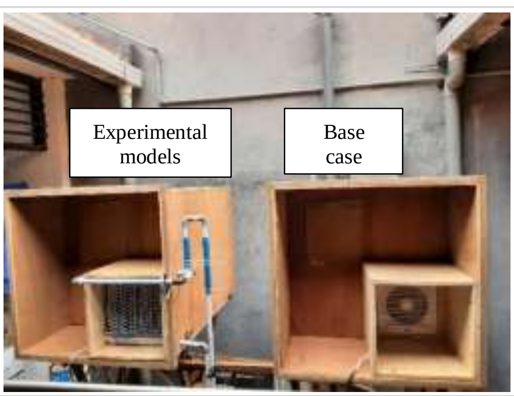
a) Housing unit



b) DEC unit

Figure 1. Drawings depicting the models used in the study

One type of fabric used in the present study is cotton. This specific material is chosen because this material can absorb water well and has high saturation efficiency, as the previous research indicated (Velasco-Gómez et al. 2020). A material can absorb more water, and its evaporative cooling performance is better. The study selected the material due to its wide usage in everyday or domestic clothing or purposes. There are three different cotton specifications considered in the study. The first is cotton used for a blanket, the second for batik base, and the last for a towel. These three materials are different in weight, thickness, and texture. Table 1 lists the characteristics of these three fabrics and the control model set for the experiment.



a) The housing unit and evaporative cooler

b) The cooling pad

Figure 2. The realization of the model

Table 1. Characteristics of the model and fabric used in the study

Code	Type of fabric	Usage	Characteristics
DEC-BTK	Cotton	Base of batik	Light, thin, and smooth
DEC-BLK	Cotton	Blanket	Medium weight and thickness, and smooth
DEC-TOW	Cotton	Towel	Heavy, thick, and rough
M0 (the control model)	No treatment	-	-

Internal and external air temperature and humidity were recorded using a thermo-hygrometer (i.e., Elitech GSP-6). The internal and external air temperature and humidity were recorded hourly and stored in a data logger. The measurements were conducted for three consecutive days for each fabric specification and taken in September and October 2021. The resulting thermal conditions of the models are analyzed by comparing data gained from the experimental and control models. A comparative analysis is carried out to indicate the ability of different fabrics to reduce air temperature and limit the increase of air humidity.

Result and discussion

Outdoor and indoor thermal conditions

Figures 3 and 4 illustrate average outdoor air temperature (To) and relative humidity (RHo) conditions during the observation. As shown in figure 3. the profile of To in the three different periods of measurements is relatively similar in terms of both hourly patterns and values. The range of To is between 29-34ºC, with the maximum temperature difference between two cases about 1.5ºC, and no significant differences are noted among the three models (figure 3.b).

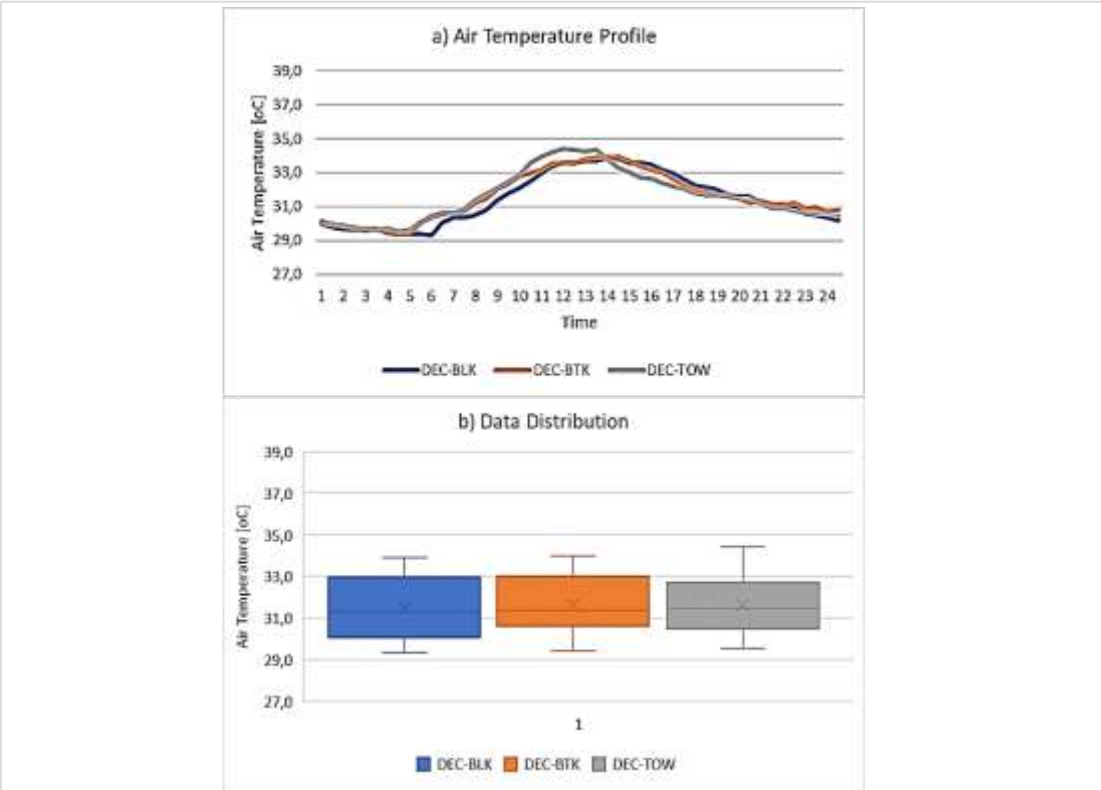


Figure 3. Outdoor air temperature measurement data

Figures 4.a and b show that the RHo of the three models shares a similar hourly pattern. A difference is recorded only in value, which gradually increases from DEC-BLK, DEC-BTK, and DEC-TOW. The value ranges between 47-74%, and 13% RH is the maximum difference.

Outdoor measurement data profiles analyzed above show that slight weather variation occurred during the measurement. This weather variation will not affect the study as the analysis will be conducted by comparing the experimental and control model. Values indicating the difference between these two models will determine their performance.

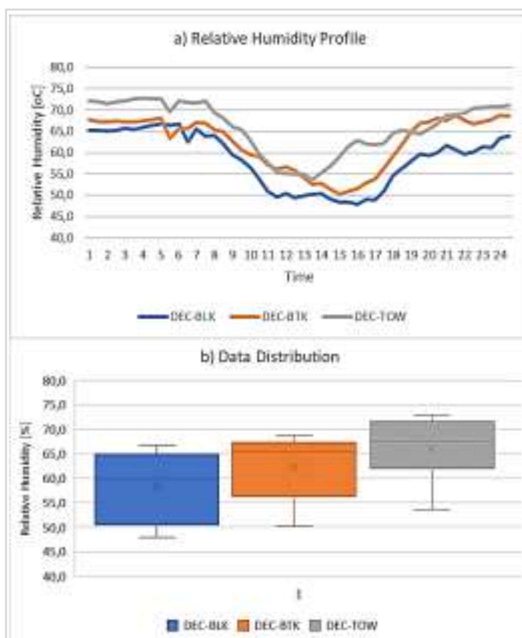


Figure 4. Outdoor relative humidity measurement data

Figures 5 and 6 illustrate the profile dan distribution of indoor air temperature (Ti) and relative humidity (RHi) for the three models. As can be seen from figure 5, Ti resulting from different fabric cooling pads are generally lower than that of the outdoor (To) and the control model (M0), which only utilizes an extraction fan. In comparison to To, Ti of the control model (Ti-M0) is slightly lower during the morning, higher between 08.00 a.m.-3.00 p.m., and almost coincides during the evening. This hourly pattern can be observed in all models. The pattern is closely linked with the material used for the model, i.e., plywood. The lightweight material tends to mimic the outdoor condition during the night as the material is easy to release heat into the environment. Conversely, the material quickly takes up the heat during the day, so the internal condition rapidly heats up. The constant ventilation rate resulting from the use of the extraction fan also contributes to lower Ti so that it will not significantly increase the temperature during the day, and it brings Ti close to To during the night.

In the case of DEC-BLK and DEC-BTK, Ti can drop as low as 28 oC and rise to 34 oC. Ti exceeds the To during the afternoon between 11.00 a.m.-3.00 p.m. The result is slightly different in the case of DEC-TOW, where Ti does not increase above To. In this model, the minimum Ti is found at 5 p.m. with a value of 28ºC. The maximum value of 34ºC occurred at noon. Overall, the Ti of the experimental models is always below Ti-M0, and the values are mostly lower than To. On this basis, the study confirms previous studies that stated DEC could give an advantage in reducing air temperature even under warm, humid climates (Mohammad et al. 2013; Yunianto 2018).

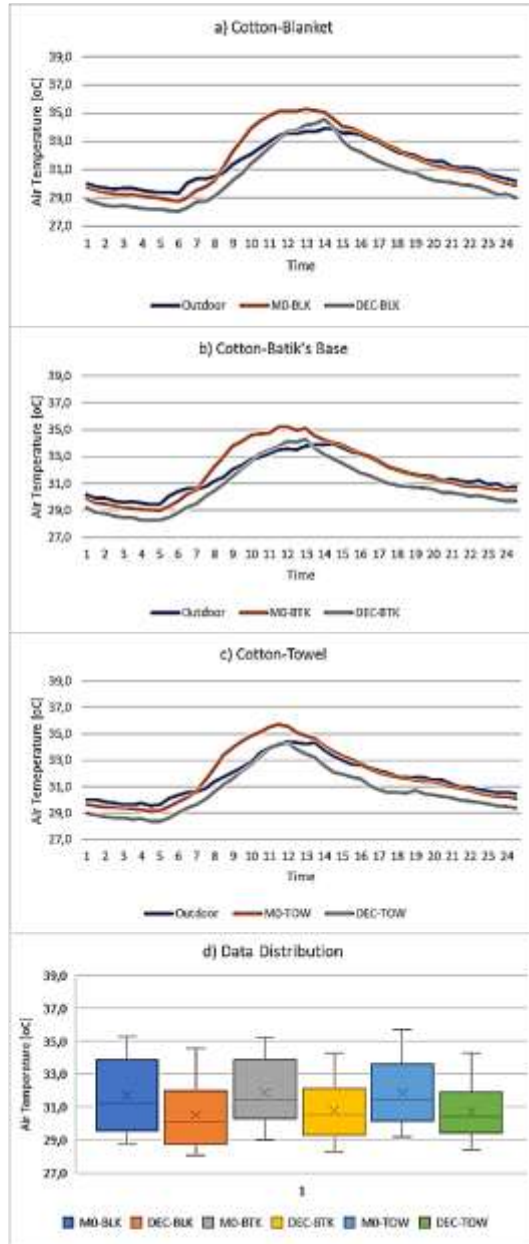
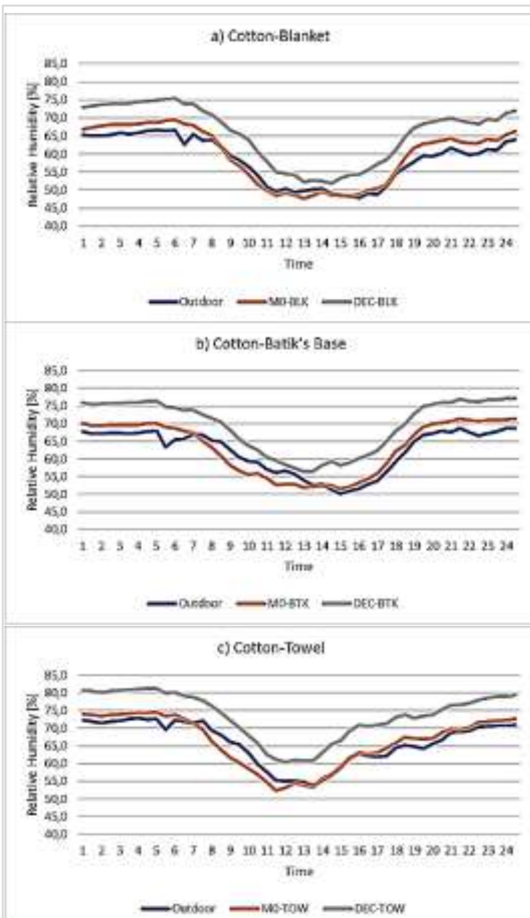


Figure 5. Results of air temperature measurement

Figure 5.d shows that different fabric specifications do not significantly influence Ti. The treatment does lower Ti, as previously stated, but the difference among the models is negligible. The slight difference in the average value of Ti between the experimental and control models confirms this inference. In DEC-BLK, the difference is 1.2ºC; in DEC-BTK, 1.1ºC, and DEC-TOW, 1.2ºC. Aside from this finding, however, the method is still considered helpful

from the thermal design perspective, particularly in the region where overheating is predominant.

The effect of different fabric specifications on RHi is depicted in figure 6. The figures present that in all cases, RH increases due to the application of the technique. Overall, RH rises from 4 up to 10%, or about a 7-15% increase. In the case of DEC-BLK, DEC-BTK, and DEC-TOW, the highest values of RHi are 76%, 76%, and 80%, and the lowest values are 52%, 56%, and 60%, respectively. The highest values are recorded at 05.00 a.m., and the lowest occurred between 12.00-2.00 p.m.



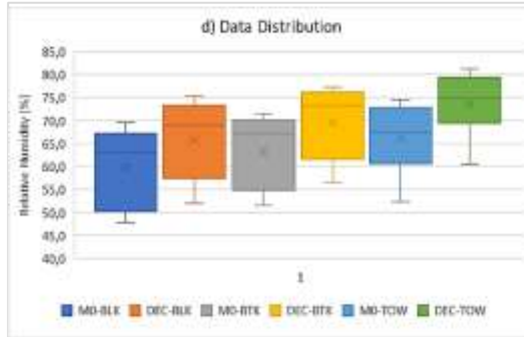


Figure 6. Results of relative humidity measurement

From the measurement data distribution depicted in figure 6.d., RHi in all models is generally higher than M0. The application of DEC facilitates the evaporation process where heat is extracted from the air, and then it changes the state of the water to the gas, thus increasing the moisture content of the air. The figure shows that the average RHi in DEC-BLK, DEC-BTK, and DEC-TOW increases from 59.8% to 65.7%, 63.2% to 69.5%, and 66,2% to 73.6%. The difference between the experimental and control models rises from 6% in DEC-BLK to 6.3% in DEC-BTK and 7.4% in DEC-TOW. From this point, it can be said that different fabric specifications could give different responses in terms of relative humidity. The following paragraphs will present a detailed analysis and discussion regarding this finding.

Influence of fabric specification on indooe thermal conditions

The influence of fabric specification is analyzed by comparing the ability of the fabric to reduce air temperature and limit the increased RH in the models (figures 7 and 8). Hourly temperature reduction illustrated in figure 7.a. shows that different fabric specifications shared similar values, especially from the late afternoon (3 p.m.) to the morning (8 a.m.). Slight differences are observed mainly during the day from 9 a.m. up to 2 p.m.

The summary of air temperature reduction is depicted in figure 7. b. indicates that temperature reduction in DEC-BLK ranges between 0.5 to 2.5 K. The maximum air temperature reduction gradually decreases in DEC-TOW (2.3 K) and DEC-BTK (2.2 K). In contrast, the minimum air temperature reduction is more or less the same in both DEC-TOW and DEC-BTK (around 0.7 K). There are also minor differences found in the case of average air temperature reduction, and the values are about 1 K in all cases. Following this result, it can be said that from the air temperature standpoint influence of different fabric specifications is very small and can be regarded as insignificant. The finding confirms the previous results of the analysis regarding the air temperature profile, where minor differences are also observed throughout the day.

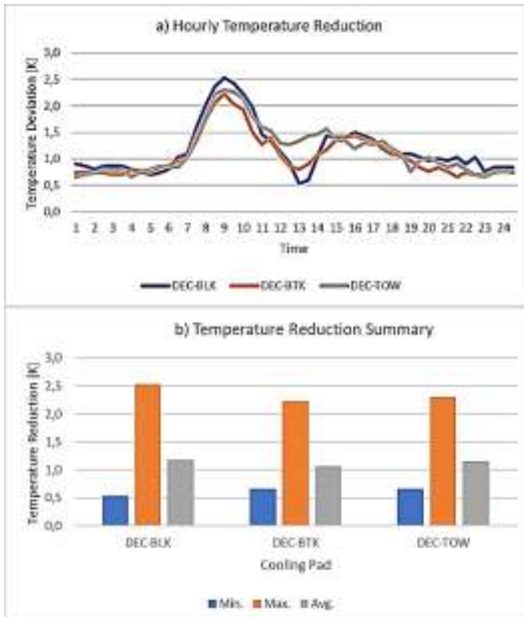


Figure 7. The air temperature reduction profile

The temperature reduction recorded in the present study is relatively low compared with that found in the previous studies. Although the value cannot be directly compared due to different factors that might affect the temperature reduction, such as thickness, airstream velocity, water temperature, and ambient thermal conditions, results from the previous research can serve as a reference. From the study of fabric-based cooling pads, temperature reduction can range from 2.1-9.1 K under a maximum water temperature of 30ºC or less (Velasco-Gómez et al. 2020). In the case of sponge material, the range is between 2-3.6 K (Suryana, Suarnadwipa, and Wijaksana 2014), and in other cases, the values are between 3.3-11.3 K (Abaranji, Panchabikesan, and Ramalingam 2020).

A similar tendency is also noted regarding the extension of the high RH in the models (figure 8.). Different fabric specifications respond similarly, especially from 3 p.m. to 8 a.m. (figure 8.a). The increased values are about 6-8% RH during this period, and the RH difference is higher during the late morning when the maximum RH difference reaches 10%. The value goes down to 3% RH in the early afternoon. This result indicates that the evaporative process fluctuates during the day when the air humidity tends to be lower. In contrast, the pattern tends to be constant during the night when the air humidity is high.

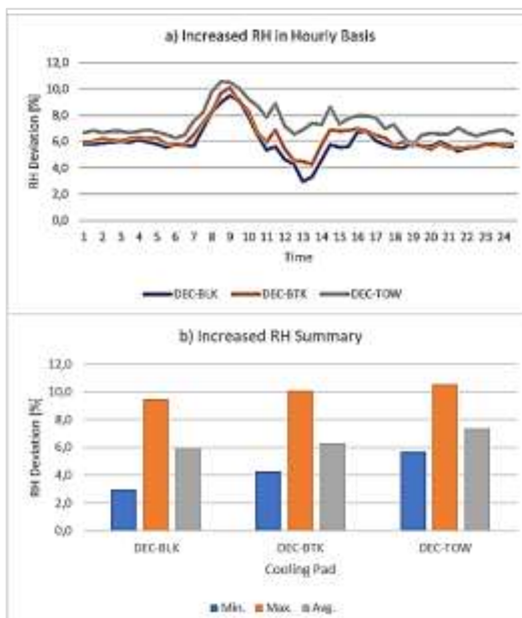


Figure 8. The increased RH profile

The summary illustrated in figure 8.b shows that different fabric specifications influence indoor RH. The minimum, maximum, and average values recorded in the models are found to progressively increase from DEC-BLK, which is the lowest, to DEC-TOW, which is the highest. According to the measurement, DEC-BTK exists between the two. The minimum values increase from 3 to 5.7% RH, maximum values from 9.5 to 10.5% RH, and average values from 6.0 to 7.4% RH. This result indicates that the DEC-BLK is the model that gives the most negligible impact in terms of air humidity. By taking the temperature reduction into account, it can be stated among the three models understudied; the DEC-BLK is the most representative model for the warm-humid climate. The reason for this is that the model can attain two objectives of applying DEC in this type of climate at the same time, i.e., can reduce air temperature and limit the impact of air humidity.

Conclusion

The above analysis and discussion show that incorporating fabric as an alternative material for a cooling pad in the evaporative cooler could help moderate thermal stress inside the housing unit. The study shows that the three fabric specifications can lower the air temperature from 0.5 to 2.5 K. No significant differences in terms of temperature reduction are found among the three models. The study also shows that the influence of the models on indoor RH is visible, and the models contribute to the increased air humidity within 3 to 10% RH. Out of the three models, the DEC-BLK gives the slightest influence with an average value of 6% RH compared to 6.3% and 7.4% RH in DEC-BTK and DEC-TWO, respectively.

Since the study's objective is to analyze the ability of the fabric to reduce air temperature and limit the increased RH, the study concludes that DEC-BLK is the suitable material and technique for the application of direct evaporative cooling in the public housing unit in warm-humid climates. The study, however, is still at the initial stage, and further studies are required to take into account other aspects of the system before it can implement the model in a real case.

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References

Abaranji, Sujatha, Karthik Panchabikesan, and Velraj Ramalingam. 2020. 'Experimental Investigation of a Direct Evaporative Cooling System for Year-Round Thermal Management with Solar-Assisted Dryer'. Edited by Kumarasamy Sudhakar. *International Journal of Photoenergy* 2020 (December): 1–24. https://doi.org/10.1155/2020/6698904.

Abohorlu Doğramacı, Pervin, Saffa Riffat, Guohui Gan, and Devrim Aydın. 2019. 'Experimental Study of the Potential of Eucalyptus Fibres for Evaporative Cooling'. *Renewable Energy* 131 (February): 250–60. https://doi.org/10.1016/j.renene.2018.07.005.

Ahmad, Hidayah, Abdul Malek, and Abdul Rahman. 2017. 'The Potential of Evaporative Cooling Window System Using Labu Sayong in Tropical Malaysia : A Review'. *Advanced Journal of Technical and Vocational Education* 1 (October): 262–72.

Alfata, M.N.F., N. Hirata, T. Kubota, A.M. Nugroho, T. Uno, S.N.N. Ekasiwi, and I.G.N. Antaryama. 2015. 'Field Investigation of Indoor Thermal Environments in Apartments of Surabaya, Indonesia: Potential Passive Cooling Strategies for Middle-Class Apartments'. *Energy Procedia* 78 (November): 2947–52. https://doi.org/10.1016/j.egypro.2015.11.674.

Alwetaishi, Mamdooh, Ashraf Balabel, Ahmed Abdelhafiz, Usama Issa, Ibrahim Sharaky, Amal Shamseldin, Mohammed Al-Surf, Mosleh Al-Harthi, and Mohamed Gadi. 2020. 'User Thermal Comfort in Historic Buildings: Evaluation of the Potential of Thermal Mass, Orientation, Evaporative Cooling and

Ventilation'. *Sustainability* 12 (22): 9672. https://doi.org/10.3390/su12229672.

Aziz, Azridjal, Rahmat Iman Mainil, Afdhal Kurniawan Mainil, and Hendra Listiono. 2017. 'Effect of Water Temperature and Air Stream Velocity on Performance of Direct Evaporative Air Cooler for Thermal Comfort'. In *AIP Conference Proceedings*, 030024. https://doi.org/10.1063/1.4968277.

Chang, Bin, Yuexi Dang, Xilian Luo, Chuck Wah Yu, and Zhaolin Gu. 2020. 'Sustainability of Evaporative Cooling System for Environment Control for Preservation of Unearthed Historical Sites within Archaeological Museums in China'. *Sustainability* 12 (23): 9882. https://doi.org/10.3390/su12239882.

Darmawan, I Made Yudi, Hendra Wijaksana, and N. Suarnadwipa. 2021. 'Performansi Pendinginan Kombinasi Sistem Direct Dan Indirect Evaporative Cooling'. *Teknik Desain Mekanika* 10 (1).

Elmsaad, Egbal, and Abdelnaser Omran. 2015. 'Evaluating the Effect of New Local Materials of Evaporative Cooling Pads'. *American-Eurasian J. Agric. & Environ. Sci.* 15 (1): 78–84. https://doi.org/10.5829/idosi.aejaes.2015.15.1.12494.

Esparza L., Carlos J., Carlos Escobar del Pozo, Adolfo Gómez A., Gabriel Gómez A., and Eduardo Gonzalez C. 2018. 'Potential of a Wet Fabric Device as a Roof Evaporative Cooling Solution: Mathematical and Experimental Analysis'. *Journal of Building Engineering* 19 (September): 366–75. https://doi.org/10.1016/j.jobe.2018.05.021.

Hussain, Shafqat, Abdulrahim Kalendar, Muhammad Zeeshan Rafique, and Patrick Oosthuizen. 2020. 'Numerical Investigations of Solar-Assisted Hybrid Desiccant Evaporative Cooling System for Hot and Humid Climate'. *Advances in Mechanical Engineering* 12 (6): 168781402093499. https://doi.org/10.1177/1687814020934999.

Indrani, Hedy Constancia. 2008. 'Kinerja Ventilasi Pada Hunian Rumah Susun Dupak Bangunrejo Surabaya'. *Dimensi Interior* 6 (1): 9–23. http://puslit2.petra.ac.id/ejournal/index.php/int/article/view/17994.

Mohammad, Abdulrahman Th, Sohif Bin Mat, M Y Sulaiman, K Sopian, and Abduljalil A Al-Abidi. 2013. 'Experimental Performance of a Direct Evaporative Cooler Operating in Kuala Lumpur'. *Int. J. of Thermal & Environmental Engineering* 6 (1): 15–20. https://doi.org/10.5383/ijtee.06.01.003.

Poku, Robert, Tokoni W. Oyinki, and Ezenwa A. Ogbonnaya. 2017. 'The Effects of Evaporative Cooling in Tropical Climate'. *American Journal of Mechanical Engineering* 5 (4): 145–50. https://doi.org/10.12691/ajme-5-4-5.

Rao, V. Venkateswara, and Santanu P Datta. 2018. 'The Acceptability of Different Types of Evaporative Cooling Systems across India'. In *5th International High Performance Buildings Conference at Purdue*, 1:1–11. School of Mechanical Engineering. https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1282&context=ihpbc.

Raza, Hafiz M. U., Hadeed Ashraf, Khawar Shahzad, Muhammad Sultan, Takahiko Miyazaki, Muhammad Usman, Redmond R. Shamshiri, Yuguang Zhou, and Riaz Ahmad. 2020. 'Investigating Applicability of Evaporative Cooling Systems for Thermal Comfort of Poultry Birds in Pakistan'. *Applied Sciences* 10 (13): 4445. https://doi.org/10.3390/app10134445.

Sajjad, Uzair, Naseem Abbas, Khalid Hamid, Saleem Abbas, Imtiyaz Hussain, Syed Muhammad Ammar, Muhammad Sultan, et al. 2021. 'A Review of Recent Advances in Indirect Evaporative Cooling Technology'. *International Communications in Heat and Mass Transfer* 122 (March): 105140. https://doi.org/10.1016/j.icheatmasstransfer.2021.105140.

Suryana, I Nyoman, I Nengah Suarnadwipa, and Hendra Wijaksana. 2014. 'Studi Eksperimental Performansi Penndingin Evaporative Portable Dengan Pad Berbahan Spon Dengan Ketebalan Berbeda'. *Jurnal Ilmiah TEKNIK DESAIN MEKANIKA* 1 (1): 67. https://repositori.unud.ac.id/protected/storage/upload/repositori/3f6ab3e0dd5382ffe23b5bbcb95d55d7.pdf.

Suryo, Sumar Hadi, Bambang Yunianto, Nazaruddin Sinaga, and Eflita Yohana. 2000. 'Performance Test of Indirect-Direct Two Stage Evaporative Cooler Based Water Sprayer with Primary Air Velocity Variation'. *Research Journal of Applied Science* 14 (12):

418–24. http://eprints.undip.ac.id/81740/1/6-Bareng_Sumar.pdf.

Susila, I Putu Pradnya, Hendra Wijaksana, and I Nengah Suarnadwipa. 2019. ‘Studi Laju Evaporasi Pada Direct Evaporative Cooling Berbahan Pad Jerami Padi Dan Tapis Kelapa’. *IPTEKMA*, February, 25. https://doi.org/10.24843/iptekma.2019.v08.i01.p04.

Suwannapruk, Natchai, Alejandro Prieto, and Christien Janssen. 2020. ‘“Desigrated”-Desiccant Integrated Façade for the Hot-Humid Climate of Bangkok, Thailand’. *Sustainability* 12 (13): 5490. https://doi.org/10.3390/su12135490.

Telis, Citra Fila, Maria Immaculata Ririk Winandari, and Sri Tundono. 2017. ‘Pengaruh Orientasi Bangunan Terhadap Suhu Termal Di Unit Rusunawa Tambora’. In *Seminar Nasional Cendekiawan Ke 3*, 51–55. Malang: LPPM Universitas Brawijaya.

Velasco-Gómez, Eloy, Ana Tejero-González, Javier Jorge-Rico, and F. Javier Rey-Martínez. 2020. ‘Experimental Investigation of the Potential of a New Fabric-Based Evaporative Cooling Pad’. *Sustainability* 12 (17): 7070. https://doi.org/10.3390/su12177070.

Warke, Dipak Ashok, and Samir Jaiwantrao Deshmukh. 2017. ‘Experimental Analysis of Cellulose Cooling Pads Used in Evaporative Coolers’. *International Journal of Energy Science and Engineering* 3 (4): 37–43. http://www.aiscience.org/journal/ijesehttp://creativecommons.org/licenses/by/4.0/.

Xu, Peng, Xiaoli Ma, Xudong Zhao, and Kevin S. Fancey. 2016. ‘Experimental Investigation on Performance of Fabrics for Indirect Evaporative Cooling Applications’. *Building and Environment* 110 (December): 104–14. https://doi.org/10.1016/j.buildenv.2016.10.003.

Yunianto, Bambang. 2018. ‘Pemanfaatan Evaporative Cooling Untuk Meningkatkan Kenyamanan Ruang’. *ROTASI* 20 (1): 29. https://doi.org/10.14710/rotasi.20.1.29-32.

Author(s) contribution

I Gusti Ngurah Antaryama contributed to the research concepts, preparation, literature review, methodologies, data analysis, article drafting, and validation.

Sri Nastiti Nugrahani Ekasiwi contributed to the preparation, literature review, methodologies, data analysis, and article drafting.

Collinthia Erwindi contributed to preparation, data collection and analysis, and visualization.